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A kinematical selection of glueball candidates in central production

The WA102 Collaboration

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Abstract

A study of central meson production as a function of the difference in transverse momentum (dP_T) of the exchanged particles shows that undisputed $q\overline{q}$ mesons are suppressed at small dP_T whereas the glueball candidates are enhanced.

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There is considerable current interest in trying to isolate the lightest glueball. Several experiments have been performed using glue-rich production mechanisms. One such mechanism is Double Pomeron Exchange (DPE) where the Pomeron is thought to be a multi-gluonic object. Consequently it has been anticipated that production of glueballs may be especially favoured in this process [1].

The Omega central production experiments (WA76, WA91 and WA102) are designed to study exclusive final states formed in the reaction

$$\mathrm{pp} \longrightarrow \mathrm{p}_f X^0 \mathrm{p}_s,$$

where the subscripts f and s refer to the fastest and slowest particles in the laboratory frame respectively and X^0 represents the central system. Such reactions are expected to be mediated by double exchange processes where both Pomeron and Reggeon exchange can occur. Theoretical predictions [2] of the evolution of the different exchange mechanisms with centre of mass energy, $\sqrt{s}$, suggest that

$$\begin{aligned} \sigma(\mathrm{RR}) &\sim s^{-1}, \\ \sigma(\mathrm{RP}) &\sim s^{-0.5}, \\ \sigma(\mathrm{PP}) &\sim \text{constant}, \end{aligned}$$

where RR, RP and PP refer to Reggeon-Reggeon, Reggeon-Pomeron and Pomeron-Pomeron exchange respectively. Hence we expect Double Pomeron Exchange (DPE) to be more significant at high energies, whereas the Reggeon-Reggeon and Reggeon-Pomeron mechanisms will be of decreasing importance. The decrease of the non-DPE cross section with energy can be inferred from data taken by the WA76 collaboration using pp interactions at $\sqrt{s}$ of 12.7 GeV and 23.8 GeV [3]. The $\pi^+\pi^-$ mass spectra for the two cases show that the signal-to-background ratio for the $\rho^0(770)$ is much lower at high energy, and the WA76 collaboration report that the ratio of the $\rho^0(770)$ cross sections at 23.8 GeV and 12.7 GeV is 0.44 ± 0.07. Since isospin 1 states such as the $\rho^0(770)$ cannot be produced by DPE, the decrease of the $\rho^0(770)$ signal at high $\sqrt{s}$ is consistent with DPE becoming relatively more important with increasing energy with respect to other exchange processes.

However, even in the case of pure DPE the exchanged particles still have to couple to a final state meson. The coupling of the two exchanged particles can either be by gluon exchange or quark exchange. Assuming the Pomeron is a colour singlet gluonic system if a gluon is exchanged then a gluonic state is produced, whereas if a quark is exchanged then a $q\overline{q}$ state is produced (see figures 1a) and b) respectively). It has been suggested recently [4] that for small differences in transverse momentum between the two exchanged particles an enhancement in the production of glueballs relative to $q\overline{q}$ states may occur.

Recently the WA91 collaboration has published a paper [5] showing that the observed centrally produced resonances depend on the angle between the outgoing slow and fast protons. In order to describe the data in terms of a physical model, Close and Kirk [4], have proposed that the data be analysed in terms of the difference in transverse momentum between the particles exchanged from the fast and slow vertices.

In this letter we present the results for centrally produced meson systems, using data from the 1995 run of the WA102 experiment, which is a higher statistics continuation of the WA91 experiment. The layout of the Omega Spectrometer used in this run is similar to that described in ref. [6] with the replacement of the OLGA calorimeter by GAMS-4000 [7].

The trigger is described in detail in ref. [5]. In brief, the trigger separates the data into two categories. One where the slow and fast particles are on the same side of the beam, *i.e.* a small azimuthal angle between the outgoing protons (classified as LL) and one where the slow and fast particles are on the opposite side of the beam, *i.e.* the azimuthal angle between the outgoing protons is near to 180 degrees, (classified as LR).

In ref. [5] it was shown that the centrally produced resonances depended on the trigger type i.e. the resonances observed in the LL trigger were different to those observed in the LR trigger. This difference was not due to any acceptance or trigger bias but appeared to be related to the angle between the outgoing protons. Figures 1c) and d) show schematic representations of the LL and LR triggers respectively in the centre of mass of the beam plus target where the longitudinal (x) axis is defined to be along the beam direction. In the case of the LL trigger (figure 1c)) the transverse momentum vector of each exchanged particle has the same sign whereas for the LR trigger (figure 1d)) they have the opposite sign. Hence the difference in the transverse momentum vectors of the two exchanged particles is greater in the LR trigger than in the LL trigger. The difference in the transverse momentum vectors (dP_T) is defined to be

$$dP_T = \sqrt{(P_{y1} - P_{y2})^2 + (P_{z1} - P_{z2})^2}$$

where Py_i, Pz_i are the y and z components of the momentum of the ith exchanged particle in the pp centre of mass system.

Figures 2a) and b) show the dP_T spectrum for the LL and LR trigger types respectively. As can be seen the LL trigger type have access to events with smaller dP_T. It has been shown by Monte Carlo simulation that this effect is not due to the fact that the LR events have additional trigger requirements but it is due only to the fact that the two protons recoil on the same (LL) or opposite (LR) side of the beam direction [5].

The effect that different cuts in dP_T have on the $\pi^+\pi^-$ mass spectrum are shown in figures 2c), d) and e). As can be seen, for $dP_T < 0.2$ GeV there is effectively no $\rho^0(770)$ or $f_2(1270)$ signals. These signals only become apparent as dP_T increases. However the $f_0(980)$, which is responsible for the sharp drop in the spectrum around 1 GeV, is clearly visible in the small dP_T sample.

Figures 3a), b) and c) show the effect of the dP_T cut on the K^+K^- mass spectrum. As can be seen, the $f_2'(1525)$ is produced dominantly at high dP_T, whereas the $f_J(1710)$ is produced dominantly at low dP_T.

In the $\pi^+\pi^-\pi^+\pi^-$ mass spectrum a dramatic effect is observed, see figures 3d), e) and f). The $f_1(1285)$ signal has virtually disappeared at low dP_T whereas the $f_0(1500)$ and $f_2(1930)$ signals remain.

Figure 4 shows a similar effect in the $\mathrm{K^0_S K^\pm \pi^\mp}$ and $\eta\pi^+\pi^-$ channels where the $f_1(1285)$, $f_1(1420)$ and η' are all more prominent in the large dP_T sample and start to disappear at low dP_T.

It would appear that the undisputed $q\overline{q}$ states (i.e. $\rho^0(770)$, η', $f_2(1270)$, $f_1(1285)$, $f_2'(1525)$) are suppressed as dP_T goes to zero, whereas the glueball candidates $f_J(1710)$, $f_0(1500)$ and $f_2(1930)$ survive. It is also interesting to note that the enigmatic $f_1(1420)$ disappears at low dP_T while the $f_0(980)$, a possible non-$q\overline{q}$ meson or $K\overline{K}$ molecule state does not.

A Monte Carlo simulation of the trigger, detector acceptances and reconstruction program shows that there is very little difference in the acceptance as a function of dP_T in the different mass intervals considered within a given channel and hence the observed differences in resonance production can not be explained as acceptance effects.

In conclusion, the undisputed $q\overline{q}$ states are observed to be suppressed at small dP_T, but the glueball candidates $f_0(1500)$, $f_J(1710)$, and $f_2(1930)$ survive.

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Figures

Figure 1: Schematic diagrams of the coupling of the exchange particles into the final state meson for a) gluon exchange and b) quark exchange. Schematic diagrams in the CM for c) LL and d) LR triggers.

Figure 2: dP_T for a) LL and b) LR triggered events. The $\pi^+\pi^-$ mass spectrum for c) $dP_T < 0.2$ GeV, d) $0.2 < dP_T < 0.5$ GeV and e) $dP_T > 0.5$ GeV.

Figure 3: K^+K^- mass spectrum for a) $dP_T < 0.2$ GeV, b) $0.2 < dP_T < 0.5$ GeV and c) $dP_T > 0.5$ GeV and the $\pi^+\pi^-\pi^+\pi^-$ mass spectrum for d) $dP_T < 0.2$ GeV, e) $0.2 < dP_T < 0.5$ GeV and f) $dP_T > 0.5$ GeV.

Figure 4: $\mathrm{K^0_S K^\pm \pi^\mp}$ mass spectrum for a) $dP_T < 0.2$ GeV, b) $0.2 < dP_T < 0.5$ GeV and c) $dP_T > 0.5$ GeV and the $\eta\pi^+\pi^-$ mass spectrum for d) $dP_T < 0.2$ GeV, e) $0.2 < dP_T < 0.5$ GeV and f) $dP_T > 0.5$ GeV.

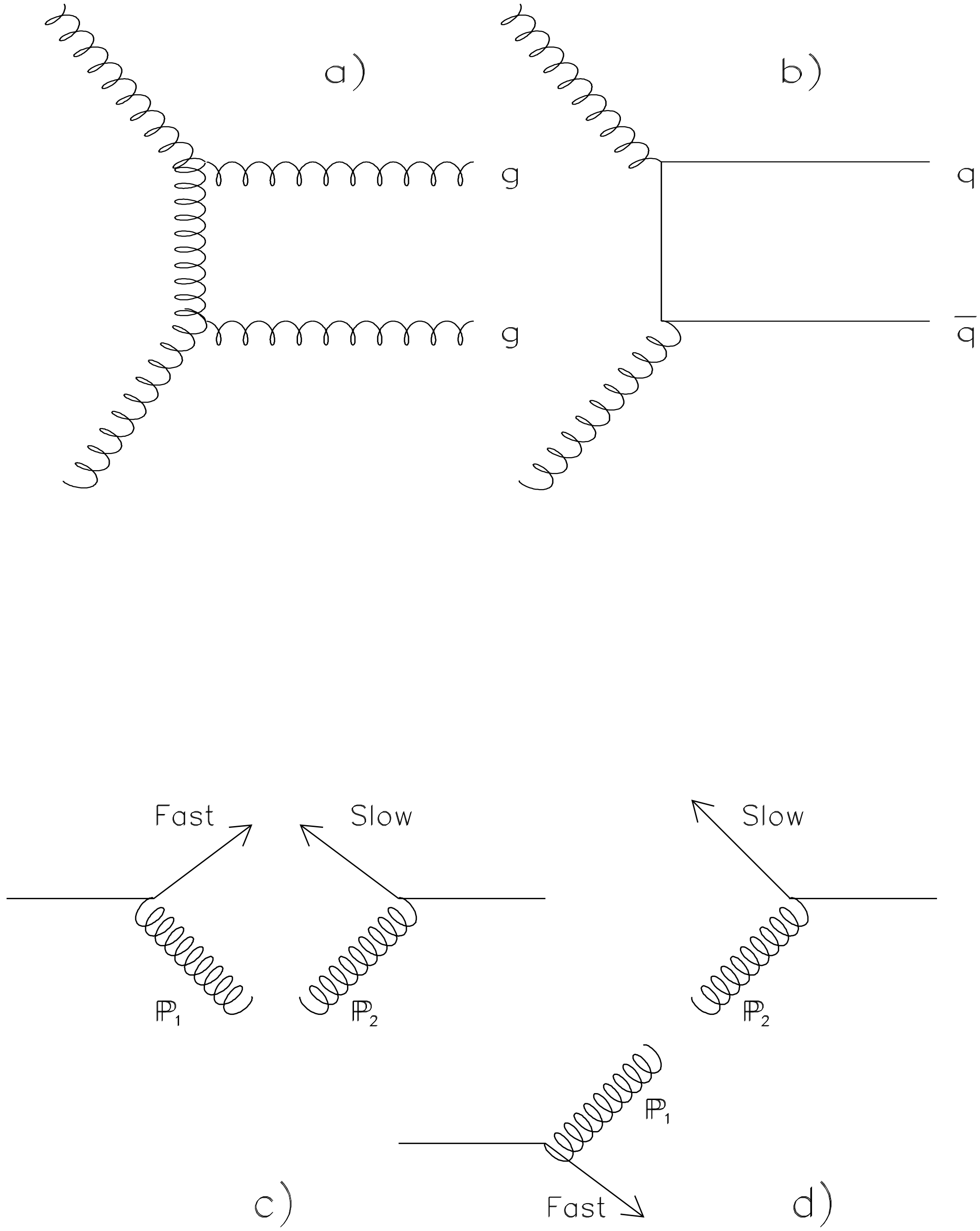
a)
g
g
b)
q
$\bar{q}$
Fast
Slow
Slow
$\mathbb{P}_1$
$\mathbb{P}_2$
$\mathbb{P}_2$
$\mathbb{P}_1$
Fast
c)
d)

Figure 1:

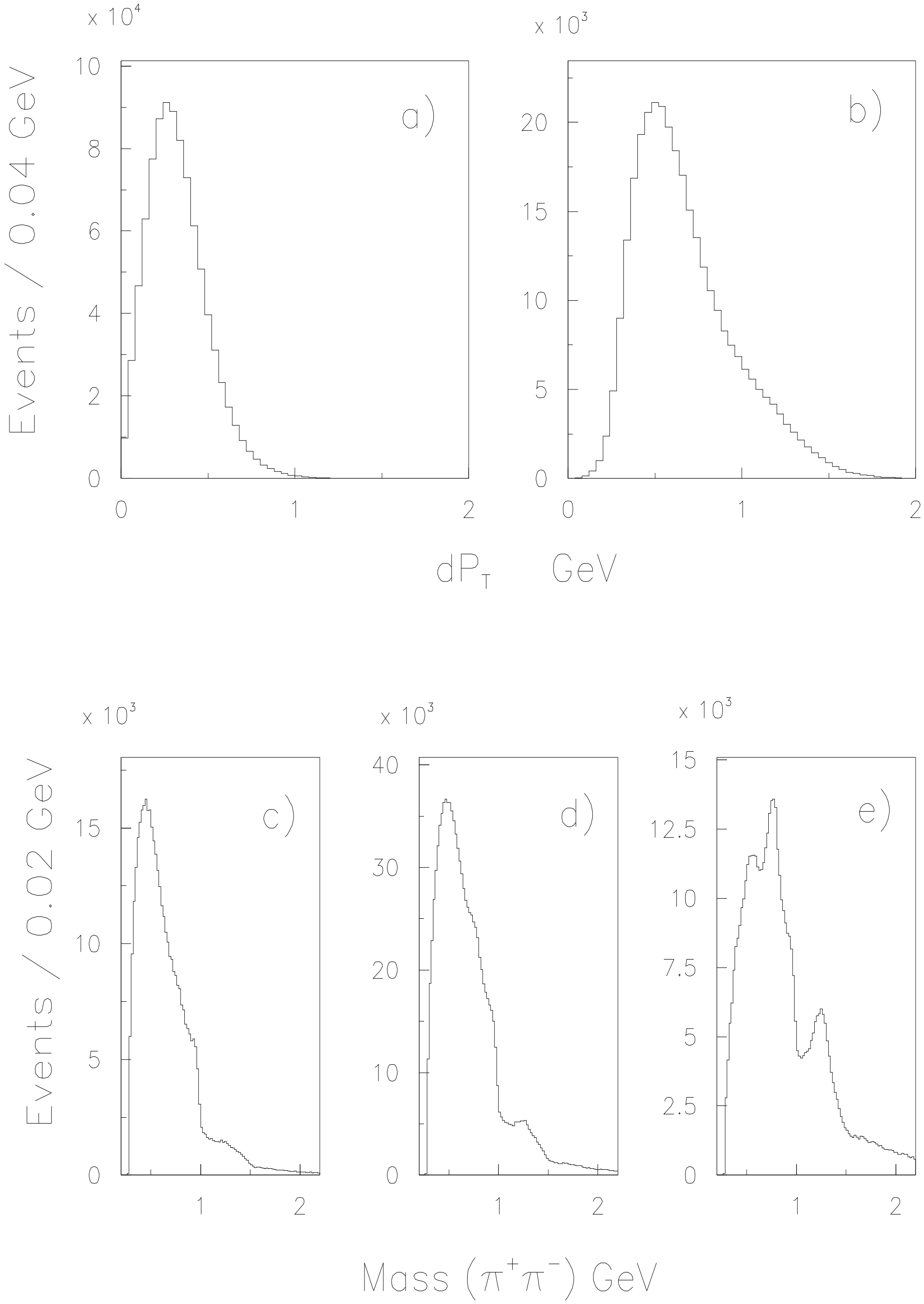
x 10^4
x 10^3
Events / 0.04 GeV
a)
b)
dP_T GeV
x 10^3
x 10^3
x 10^3
Events / 0.02 GeV
c)
d)
e)
Mass (π⁺π⁻) GeV

Figure 2:

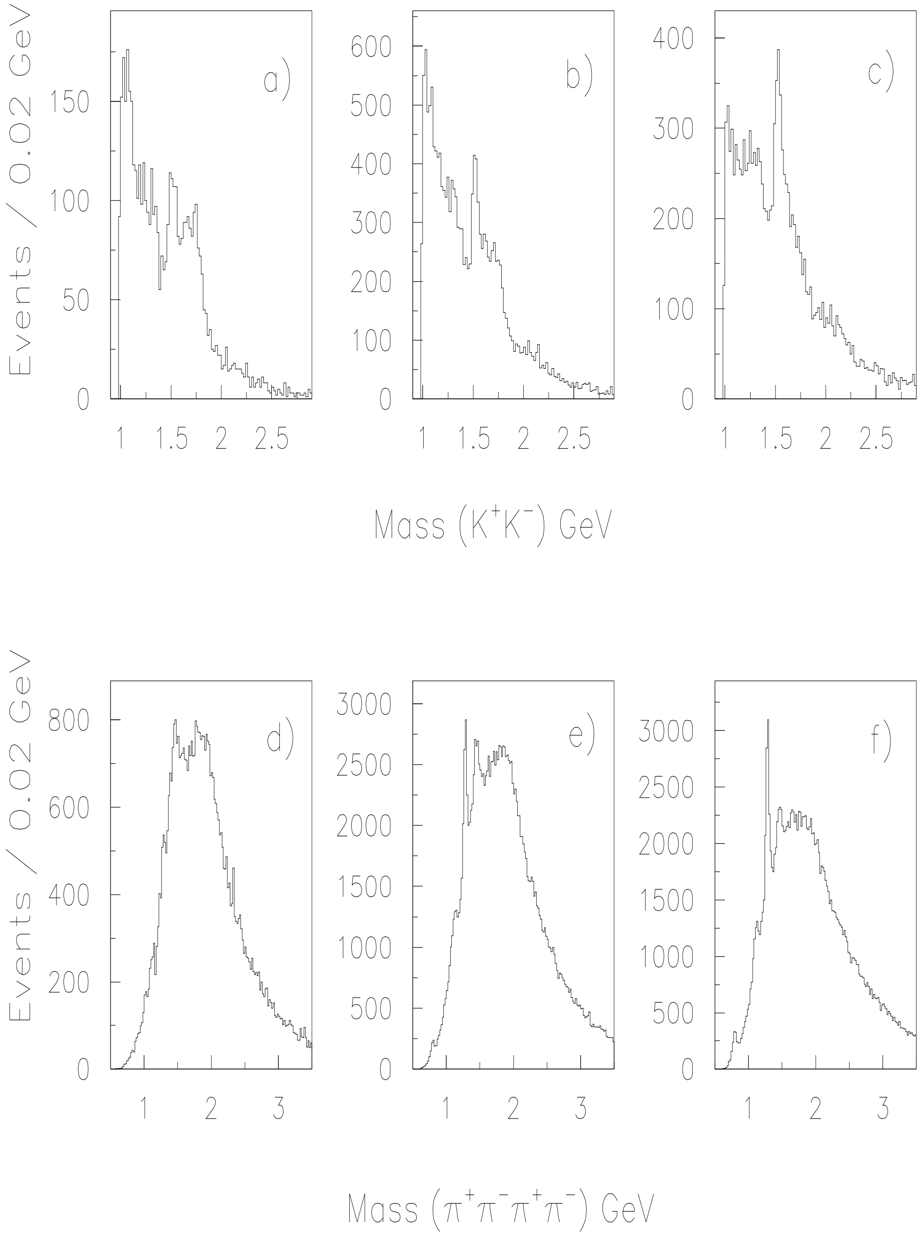
Events / 0.02 GeV
a)
b)
c)
Mass (K+K-) GeV
Events / 0.02 GeV
d)
e)
f)
Mass (π+π-π+π-) GeV

Figure 3:

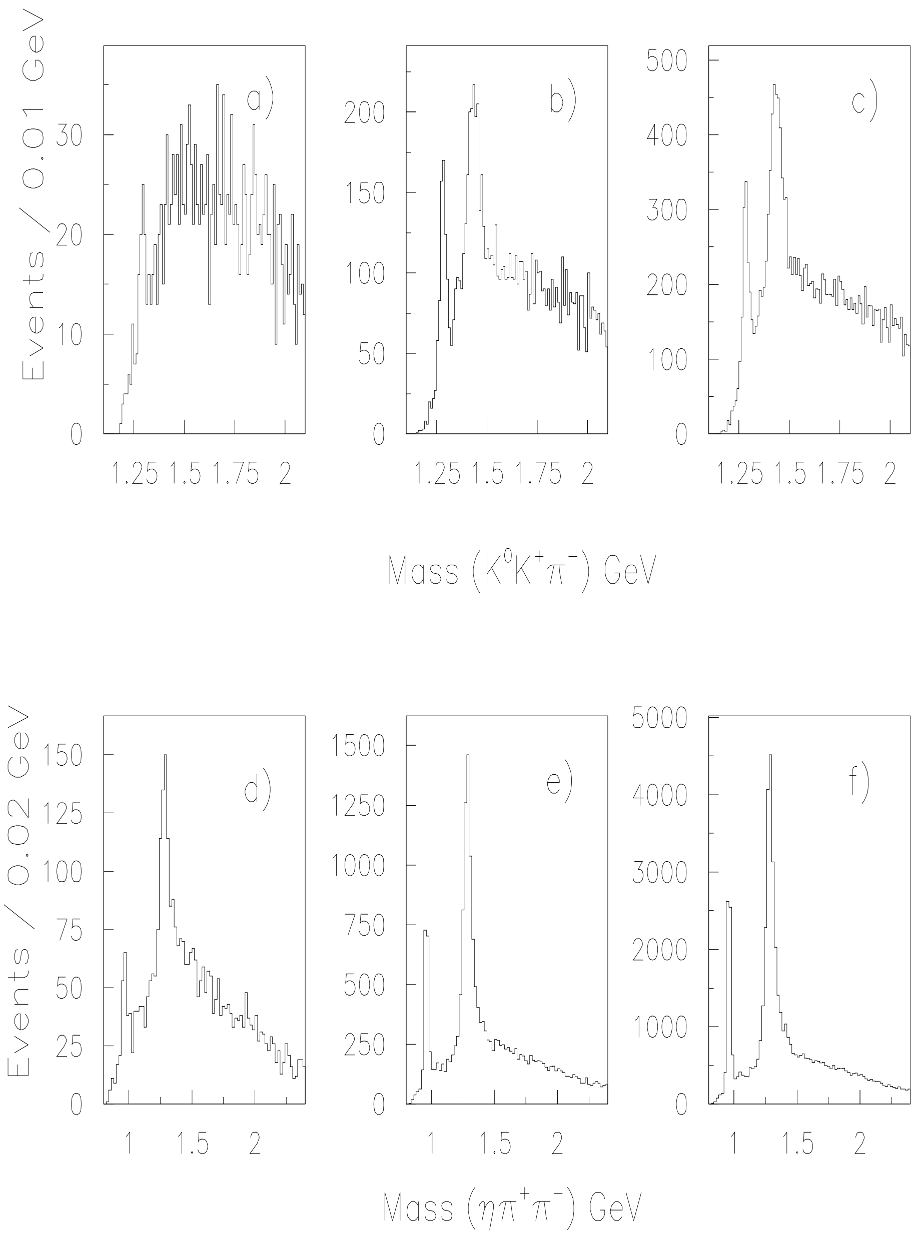
a)
b)
c)
Events / 0.01 GeV
Mass ($K^0K^+\pi^-$) GeV
d)
e)
f)
Events / 0.02 GeV
Mass ($\eta\pi^+\pi^-$) GeV

Figure 4: